Urol Res (2011) 39:205–212
DOI 10.1007/s00240-010-0336-8

ORIGINAL PAPER

Ultrasound-guided X-ray free percutaneous nephrolithotomy for treatment of simple stones in the flank position

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Received: 18 July 2010 / Accepted: 20 October 2010 / Published online: 11 November 2010

Abstract The purpose of this study was to examine the effectiveness and safety of percutaneous nephrolithotomy with ultrasonography-guided renal access in the flank position without the use of fluoroscopy in any stage of the procedure. Percutaneous nephrolithotomy was performed in flank position under the guidance of ultrasound (USG) without the use of fluoroscopy between December 2008 and January 2010 on 43 patients who had kidney stones bigger than 20 mm. Access to the kidney's proper calyx was achieved by dilatation through the guide wire placed after insertion of the needle through the needle director under the guidance of transrectal ultrasound probe placed on the patient's flank area. A convex USG probe was used for imaging during dilatation and lithotripsy instead of fluoroscopy. Access to the targeted calyx was achieved successfully in all patients (100%). The percentage stone free rate was 86.1% (37 patients). Residual stones were detected in six patients. Their dimensions ranged from 5 to 12 mm. The mean stone diameter was 29 (20–41) mm, duration of surgery was 87.1 ± 43.2 (55–210) min and duration of hospital stay was 3.1 (2–8) days. Blood transfusions were given to two patients; none of the patients had major intraoperative or postoperative complications. In comparison with standard percutaneous nephrolithotomy, percutaneous nephrolithotomy in flank position under ultrasonographic imaging instead of using fluoroscopy seems to be safe and effective. This procedure has to be limited to selected cases with one or maximum two big stones in the pelvis or in a single calyx in absence of complex intrarenal anatomy. Both surgical team and the patients were protected from the harmful effects of radiation. Regarding anesthesia, flank position is more comfortable for the patient than prone position.

Keywords Percutaneous nephrolithotomy · Ultrasonography guided renal access

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Introduction

Percutaneous nephrolithotomy (PNL) is an effective treatment method for large and complex kidney stones [1, 2]. The benefit of low early morbidity, early return to work and recreational activities has also popularized PNL for the treatment of renal calculi [3].

Percutaneous nephrolithotomy is generally performed with fluoroscopy guidance. Hence it has increased the exposure of the surgical team and patients to the possible deleterious effects of radiation. The severity of the stochastic effects of X-rays, which cause genetic mutations and cancer, is not dose-dependent. To protect against these effects, highly advanced fluoroscopies and protection shields are available, although none is completely effective [4]. To reduce the disadvantages of fluoroscopies, ultrasonography (USG) can be useful to access the collecting system and in the dilatation of the tract.

Another drawback of PNL is the prone position, which is not suitable for patients who are obese and have cardiopulmonary risks or skeletal deformities [5]. There are very few studies about reducing these two major disadvantages (surgical position and harmful effect of X-rays) of classical PNL. Using ultrasonography as a guide for renal access and placing the patient in the flank position for all stages of the operation has been completed successfully in previous studies [6–8].

In our center, we adopted ultrasound-guided PNL in the flank position to avoid being exposed to radiation and the discomforts of surgical position. The aim of our study was to evaluate the applicability of the three published studies, and in the light of the results, to attract attention to the practical aspects of our technique.

Patients and methods

After receiving ethical committee approval and patient informed consent, 43 patients with kidney stones bigger than 20 mm underwent PNL with USG-guided renal access in flank position between December 2008 and January 2010. Patients who had higher risk for anesthesia, single kidney, horseshoe kidney and pelvic kidney patients were excluded. Because of prior experience patients with body mass index (BMI) greater than 30 kg/m^2, and patients who had staghorn stones or more than two stones were also excluded.

Interventional radiologists were not included in any of the operations and all surgery was performed by a single surgical team. Cystoscopy was carried out under general anesthesia and a 5F open end ureteral catheter was inserted into the ureter and its distal tip was closed. The patients were secured in the standard flank position after ureteral catheter insertion. A balloon dilator was not used to occlude the ureter, and the pyelocaliceal system was not distended with a saline injection. If there was grade 0 hydronephrosis, instead of a saline injection, we infused 20–40 mg furosemid for enforcement of diuresis. Because of the closed ureter catheter and forced diuresis, grade of dilatation of collecting urinary system was increased in one degree via a physiological pathway. Then, the pyelocaliceal system status and stone location were determined with both convex and transrectal ultrasound (TRUS) probe of the back and lateral side walls of the abdomen (Fig. 1). Grade 1 calyceal ectasia was sufficient to access the targeted calyx.

After attachment of biopsy apparatus to the TRUS probe, using its biopsy lines, an 18-gauge needle was used to puncture the appropriate calyceal fornix (Fig. 2). The puncture was positioned at the most convex point of the targeted calyx under guidance of the TRUS probe from a

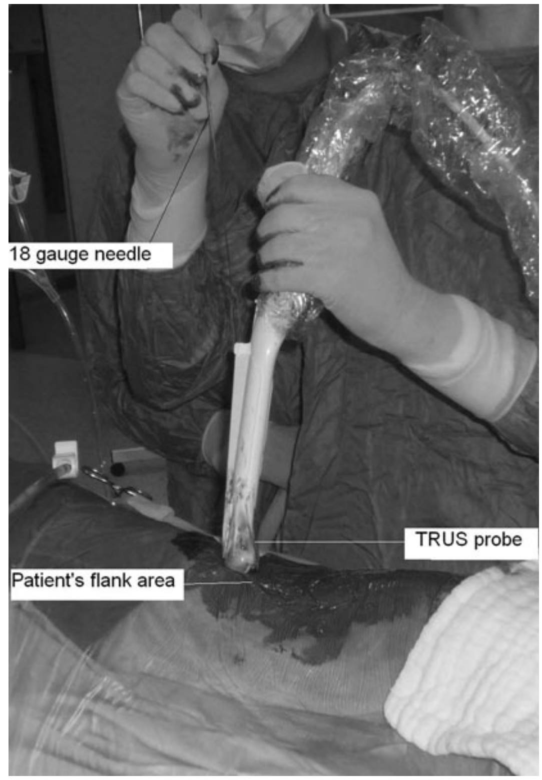

Fig. 1 The pyelocaliceal system status and stone location were determined with transrectal ultrasound (TRUS) probe

point between the mid axillary line and paraspinal muscles. In the presence of anatomical anomalies such as splenomegaly, a safe window was created by using USG findings and renal access was achieved without adjacent organ injuries.

We preferred longitudinal scanning of the kidney by TRUS probe when puncturing through the cup of the desired calyx, permitting a peripheral puncture, traversing minimum cortical tissue, avoiding injury to any major

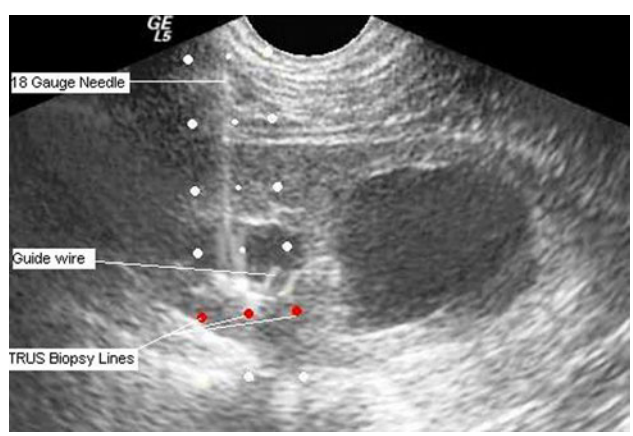

Fig. 2 Using with biopsy lines, an 18-gauge needle was used to puncture the appropriate calyceal fornix shown in figure

intrarenal vessel, avoiding visceral injury, and establishing the shortest straight tract between the skin and calyx. We punctured the targeted calyx when calyx and stone localized in the same plane as observed by longitudinal scanning of the kidney (Fig. 3). Thereby calyces do not superpose each other under sonographic evaluation.

A soft-tipped 0.097 mm guide wire was inserted through the needle and placed into the targeted calyx. The needle was removed, and the exact distance between the skin and the targeted calyx was measured. The tract was dilated by elastic semi rigid dilatators until 28F. During dilatation, normal 3–5 ml shaken (to produce micro air bubbles) saline was always infused through each dilator while the guide wire was in the dilator. If the dilators were in the pelvicalyceal system, a saline jet with air bubbles could be detected by USG (Fig. 3). Thus, the surgeon could be assured about the location of dilators in the urinary system. We never required a USG contrast agent.

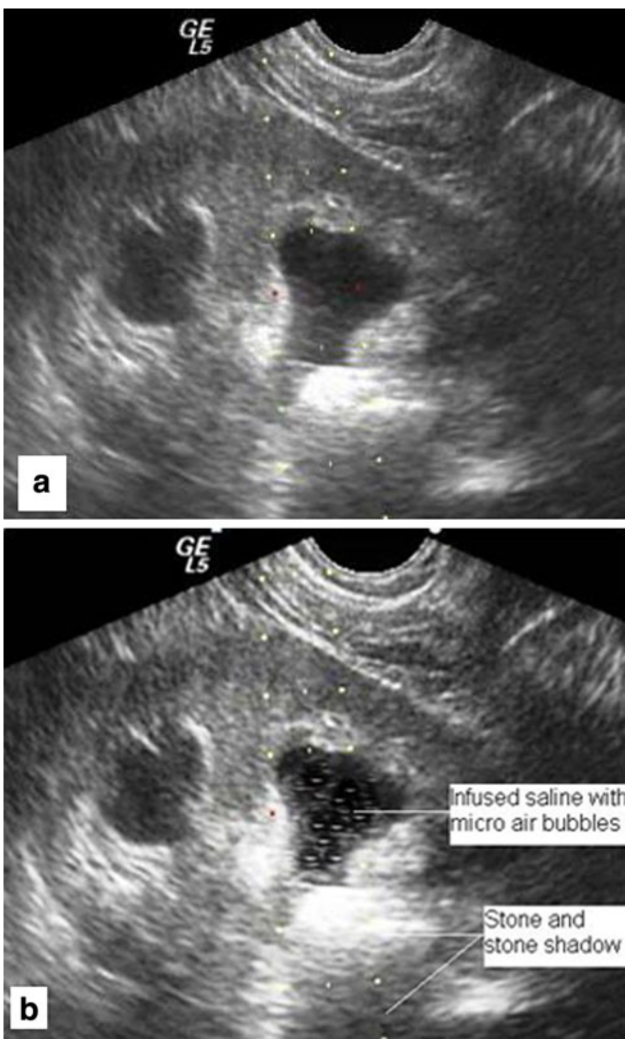

Fig. 3 We punctured the targeted calyx when calyx and stone localised in the same plane as observed by longitudinal scanning of the kidney as shown in figure

Because of the possibility of medial and superior movement of kidney in flank position and thus of instrument results being offset, to minimize renal mobility we attempted to do both puncture of the system and tract dilation at the same phase of respiration (inspiration or expiration).

After the completion of dilatation, a 26F Amplatz sheath was placed into the kidney. The second guide wire advanced through the open end ureteral catheter and was detected by nephroscope. Then it was extracted through the Amplatz sheath. Thus we accomplished the so-called “through and through access” procedure. Owing to through-and-through access extraction of the stone, confirmation of stone free status by nephroscopy and insertion of nephrostomy tube was performed safely.

At the end of the procedure, stone free status was checked by USG and nephroscope, and 16F or 18F Nelaton catheter was used instead of a nephrostomy tube in order to reduce operation cost.

A blood count was performed in the first day postoperation to assess the hematocrit level change. KUB, antegrade nephrostography and urinary system ultrasonography were conducted to detect residual stones, extravasation or perirenal urinary collection in the postoperative second day. Stone fragments smaller than 5 mm were accepted as clinically insignificant residual fragments (CIRF). The success of surgery was evaluated according to the following criteria; percentage of successful entries, stone free status, transfusion requirements, visceral organ injury, operation time, mean reduction rate of hematocrit and hospitalization time.

Results

Demographic and clinical features of patients, and results of our technique are shown in Tables 1 and 2. Operation time was defined as time from TRUS probe placement to the patient’s flank area until nephrostomy tube fixation to the patient’s skin. We can easily reach each targeted calyx by using a biopsy attachment as needle director and by imaging with TRUS probe. Targeted calyx puncture and guide wire placement was performed in all patients (100%) but placing the Amplatz sheath to the first accessed calyx was performed in 35 patients (81%). The guide wire was removed due to instrument results being offset from the kidney during the tract dilatation in eight patients. The Amplatz sheath was placed after dilatation of the same calyx puncture in six patients and different calyx puncture in 2 patients. None of the patients required open surgery or operation delay.

Table 1 Demographic and clinical features of patients

Characteristics	Values
Age	26.4 (20–41)
Gender	
Male	33
Female	10
Body mass index (kg/m^2)	23.4 (19.6–29.8)
26 kg/m^2 ↑	16
26 kg/m^2↓	27
Right kidney	25
Left kidney	18
Total length of stone	29 mm (20–41)
Stone location	
Pelvis	20
Upper calyxeal group	6
Lower calyxeal group	9
Pelvis + Calyx	8
Staghorn	0
Stone surgery story	
Open surgery	5
PNL	2
Grade of hydronephrosis	
Grade 0	4
Grade 1	9
Grade 2	17
Grade 3	13
Non-opaque stones	5

There were no major intraoperative or postoperative complications. None of the patients experienced injuries to the adjacent organs. In one patient who underwent open surgery previously, fluid accumulation occurred in his intraperitoneal area.

In six patients (13.9%) residual stone was detected in their kidneys ranging in size between 5 and 12 mm (mean 8.4 mm). Four patients underwent shock wave lithotripsy (SWL). Two patients did not accept an additional treatment for residual stones in the lower calyx. Four of six patients with residual stones larger than 5 mm and who required additional treatment were within the first ten patients of the group. When we performed the first ten PNL we only had a pneumatic lithotripter. We used Swiss LithoClast (EMC, Nyon, Switzerland) in later surgeries of the 37 patients (86.1%) who were confirmed stone-free. If we exclude the first ten patients the stone-free rate was 93.9% in the latter 33 patients. There were residual stones smaller than 5 mm in 16 patients. In this group nine patients' stones passed spontaneously within 4 weeks after PNL.

Antegrade nephrostography was performed in second day after surgery and we determined collecting system perforation in only one patient. Adjacent organ injury did not occur in any patient. Only two patients required blood transfusions because of symptomatic anemia. These two patients were in first ten-patient group where the decrease in the average hemoglobin level was determined as 2.2 g/dl. Leukocytosis with fever occurred in only two patients and these patients were treated with third-generation cephalosporin.

Discussion

This study presents our first results of PNL performed without fluoroscopy in flank position. Our study is the fourth after studies by Karami, Basiri and Hosseini [6–8] where all stages of the operation were performed under guidance of USG in flank position.

Percutaneous nephrolithotomy is performed under fluoroscopy in most centers worldwide, as it has the advantage of being a one-stage procedure. Fluoroscopy has been used at almost every step of PNL, including percutaneous renal access, dilation of the tract and stone manipulation [9]. Long-term X-ray exposure may cause deleterious effects for both patient and physician. Bush et al. [10] reported that radiation doses to the small field or region of fluoroscopy on the skin surface anterior to the kidney averaged 25 rem (0.25 Sv). In this study mean fluoroscopy times were 8 min. Mean radiation doses per diagnostic radiological procedure are 664 mrem for KUB, 4 rem for excretory urogram and 4.4 rem for abdominopelvic computerized tomography [11]. In this case, a patient may be exposed to radiation 6–7 times higher than an abdominopelvic computerized tomography during PNL.

According to International Commission of Radiological Protection (ICRP 60) report, recommended doses for radiation workers per year are 150 mSv to the lens of the eye, 500 mSv to the extremities and 20 mSv to the whole body [12]. Safak et al. [13] reported that the mean fluoroscopy times for PNL examination were 12 min and mean radiation doses per procedure of 33, 26 μGy and 12 µSv to the fingers, eyes and the whole body. According to their study urologists can perform 1,569 examinations per year within safe radiation exposure limits. Those limits are valid for deterministic effects. Skin changes such as erythema, ulcers, telangiectasia, and dermal atrophy are deterministic effects. Such effects occur only when the radiation dose exceeds a certain threshold. Radiation-induced cancer is a stochastic effect that may be induced at any dose; that is, no threshold dose is involved. Its severity is independent of dose, although the probability of occurrence increases as dose increases. Some authors advocate regular follow-up to detect possible malignancies in patients with high radiation doses [14].

Table 2 Completely ultrasonography-guided PNL results

Successful access	43 patients (100%)
Tract establishment after initial access	35 patients (81%)
Completely stone clearance	37 patients (86.1%)
Residual renal stone (5–12 mm)	6 patients (13.9%)
Average reduction of haematocrit	2.2 g/dL
Operation time	87.1 ± 43.2 min (55–210)
Hospital stay time	3.1 day (2–8)
Collecting system access	
Lower calyx	24 patients
Middle calyx	12 patients
Upper calyx	7 patients
Skin entrance	
Middle axillary line	23 patients
Posterior axillary line	20 patients
Access over 12. rib	6 patients (16.2%)
Residual stone determination rate by USG	5 out of 6 patients (%83.3)
Treatment requiring fever	2 patients (4.6%)
Adjacent organ injury	0
Major vascular injury	0
Transfusion requirement	2 patients (4.6%)
Collecting system perforation	1 patient (2.3%)
Angiography requirement	0
Intraperitoneal fluid accumulation	1 patient (2.3%)

Guidance by USG can reduce the harmful effects of X-ray in renal access. Nephrostomy catheter insertion by USG guidance had a higher success rate and also a lower complication rate [15]. Avoidance of ionizing radiation, short operation time, reduction in the number of access points and not being exposed to contrast allergy are some of the advantages of USG guidance. Additionally, the tissues between the skin and kidney can be identified, so possible organ damage can be prevented during renal access [16, 17]. A combination of fluoroscopy and USG can decrease the duration of fluoroscopy in PNL [18, 19]. Also the European Association of Urology (EAU) recommends USG-guided puncture in PNL. Lesions to adjacent organs are major (but rare) complications that can be avoided by USG [20].

In our study, as in similar studies from Iran, fluoroscopy was never used. Both renal access and tract dilatation were performed with the guidance of USG. In addition, at the end of PNL, residual stone check was also performed with USG. The investigation of residual stones by USG is better in patients with nonopaque or semi-opaque stones that are not detectable by fluoroscopy.

Kidney imaging with a convex probe at the level of 12th costa has some drawbacks in flank position. These drawbacks can be resolved by using a small probe. In order to perform this procedure easily, we propose that a probe placed on flank or intercostal region and a long grooved needle director that never allows needle movement would be useful. In this manner we considered that a TRUS probe (GE logiq 5 pro) was suitable to resolve this issue. In imaging the kidney with TRUS probe and choosing the calyx for access, we did not encounter problems in subjects whose BMI was lower than 26 kg/m^2. We gained sufficient acuity by applying pressure to the skin of patients whose BMI was between 26 and 30 kg/m^2. We claim that accessing the kidney by using the TRUS probe may reduce the learning curve of this technique. Grade 1 hydronephrosis was sufficient for renal access with TRUS probe in our study. In four non-dilated cases we established grade 1 hydronephrosis by 20–40 mg furosemid in the same way as Sanjay et al. did [21].

Our stone-free rate (86.1%) was similar to other studies and we did not need to redo PNL for the patients who had residual stones. Our stone-free rate was comparable with the rates gained from PNL results done in prone position with fluoroscopy [22, 23]. Four of six patients with residual stones larger than 5 mm who required additional treatment were within the first ten patients. Probably due to the learning curve of the surgical team and use of a pneumatic lithotriptor, these four failures occurred in the first ten cases.

EAU 2010 guidelines define stone residuals with a diameter of $\leq$4 mm as residual fragments. Their spontaneous pass rate is 68%. The term ‘clinically insignificant residual fragments’ (CIRF) has been a matter of concern and debate [24–26]. Rassweiler [27] claimed that CIRFs were considered to be 4 mm or less, non-obstructing, non-infectious, and asymptomatic residual fragments. The longest follow-up period for CIRF was reported by Yu et al. [28] After 6.3 years, stone growth was observed in 26% of patients and recurrent stone formation in 15%. In our study of 16 patients at a 3-month checkup post operation, in 12 patients stones were passed spontaneously.

Osman et al. reported that residual stones were detected in 62 renal units by CT among 100 renal units. Sensitivity was 40.3% for KUB and 37.1% for USG. Sensitivity for detecting significant residual stones was 58.3% for KUB and 41.6% for USG. Sensitivity for detecting CIRF was 15.3% for KUB and 30.7% for USG [29]. We confirmed stone-free status during the operation using nephroscope and USG. Rather than rigid nephroscopy, flexible nephroscopy may be useful in confirming stone-free status, but we did not have a flexible nephroscope in our clinic. Residual stones were detected by KUB on the second day after surgery. According to KUB, sensitivity of intraoperative USG for detecting significant residual stones and CIRF were 83.3 and 87.5%, respectively. Because of the increasing risk of hemorrhage, we did not try to extract significant residual stones which were detected by intraoperative USG. We claim that intraoperative USG is as effective as KUB and conventional portable C-arm fluoroscopy in detection of residual stones.

Andrew et al. reported that flexible nephroscopy combined with high-magnification rotational fluoroscopy (not conventional portable C-arm fluoroscopy) allows sensitive and specific intraoperative detection of residual fragments. According to their results the sensitivity of intraoperative imaging (via flexible nephroscopy combined with high magnification rotational fluoroscopy) with reference to the gold standard of postoperative CT was 40, 38 and 100% at thresholds of 0, 2 and 4 mm, respectively. Specificity was 100, 94 and 95%, respectively [30].

Percutaneous nephrolithotomy is generally performed in prone position. This position has some drawbacks [31, 32] such as a decrease in cardiac index [33], internal carotid artery dissection [34], carotid artery occlusion [35], tracheal compression [36], shoulder dislocation [37], hepatic ischaemia [38] and postoperative vision loss (mostly due to corneal abrasion) [39]. PNL may be risky in prone position in patients who have cardiopulmonary problems and morbid obesity. One of the most important of the risks is repositioning the patient from supine to prone position under general anesthesia [31]. Posture change may be impossible especially for those who have hip and lower extremity contracture [40]. Flank position, resulted in less restriction of the respiratory-dependent movement of the chest wall, and it facilitated ventilation and anesthesiologic access to the endotracheal tube, especially in obese patients [32]. Gofrit et al. [41] also suggested performing PNL in morbidly obese and kyphotic patients in the flank position.

This study had some limitations; for example, it was not a randomized case–control study, subjects were selected by means of lower stone burden and a BMI not more than 30 kg/m^2, case number was not enough for full assessment, a flexible nephroscope was not used for stone search and postoperative stone-free status was not confirmed by CT scanning.

Because the patients included in this study were elected by means of age and BMI, we cannot determine the advantages of PNL in flank position in patients who have heart–lung and skeletal anomalies. We believe that due to the difficulty in imaging kidneys by USG in those who have high body mass index, and the high chance of simultaneous obesity-induced problems in heart–lung disordered patients, performing PNL with USG would not be efficient in such patients. The flank position was chosen because it provides better scanning of the kidney by USG from anterior and lateral sides of abdomen rather than anesthetic comfort.

Finally, it seems too risky to perform a percutaneous renal procedure without the availability of an X-ray equipment in the operating room. In the case of complications or subentrating intraoperative difficulties the use of X-ray could be helpful. Although there were no major intraoperative or postoperative complications in our technique, we suggest that it is possible to perform PNL using ultrasonographic guidance, but fluoroscopy should be available in the operating room.

Conclusion

The results of PNL performed in flank position in patients whose BMI is lower than 30 kg/m^2 and who had stones between 2 and 4 cm in size with full guidance by USG are similar to the results of same procedure performed in prone position with guidance by fluoroscopy. This procedure has to be limited to selected cases with one or maximum two big stones in the pelvis or in a single calyx in the absence of complex intrarenal anatomy.

Targeted calyx puncture was very easy by using the biopsy attachment as needle director and by imaging with TRUS probe. Therefore, the learning curve of renal access is lower in our technique.

Using USG for imaging in every stage of the operation may prevent the surgical team and patient from exposure to the harmful effects of radiation, and the risk for adjacent tissue and organ injury may be lower. Also non-opaque and semi-opaque stones can be imaged more precisely and cured easily.

The flank position is well-known by urologists. In our technique the operation starts in flank position and there is no need for repositioning to prone position during the operation. The complications related to position change can be prevented by flank position.

According to our experiences, PNL can be performed safely and effectively by using USG without using fluoroscopy for patients who have only one stone in their kidneys. The results of our technique should be confirmed by randomized studies before use in future routine urologic practice.

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